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A NEURAL NETWORK-BASED ENRICHMENT OF REPRODUCING KERNEL APPROXIMATION FOR MODELING BRITTLE FRACTURE

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ABSTRACT

Numerical modeling of localizations is a challenging task due to the evolving rough solution in which the localization paths are not predefined. Despite decades of efforts, there is a need for innovative discretization-independent computational methods to predict the evolution of localizations. In this work, an improved version of the neural network-enhanced Reproducing Kernel Particle Method (NN-RKPM) is proposed for modeling brittle fracture [1, 2]. In the proposed method, a background reproducing kernel (RK) approximation defined on a coarse and uniform discretization is enriched by a neural network (NN) approximation under a Partition of Unity framework. In the NN approximation, the deep neural network automatically locates and inserts regularized discontinuities in the function space. The NN-based enrichment functions are then patched together with RK approximation functions using RK as a Partition of Unity patching function. The optimum NN parameters defining the location, orientation, and displacement distribution across location together with RK approximation coefficients are obtained via the energy-based loss function minimization. To regularize the NN-RK approximation, a constraint on the spatial gradient of the parametric coordinates is imposed in the loss function. Analysis of the convergence properties shows that the solution convergence of the proposed method is guaranteed. The NN enrichment allows the modeling of evolving cracks by a fixed coarse RK discretization without adaptive refinement for enhanced computational efficiency. The effectiveness of the proposed method is demonstrated by a series of numerical examples involving damage propagation and branching.

REFERENCES

[1] J. Baek, J. S. Chen and K. Susuki, A neural network-enhanced reproducing kernel particle method for modeling strain localization, *Int. J. Numer. Methods Eng.*, **123**, 4422–4454, 2022.

[2] J. Baek and J. S. Chen, A neural network-based enrichment of reproducing kernel approximation for modeling brittle fracture, *Comput. Methods Appl. Mech. Eng.*, **419**, 116590, 2024.